

Antennas 101

**“Don’t Be a 0.97 dB
Weakling!”**

Ward Silver NØAX

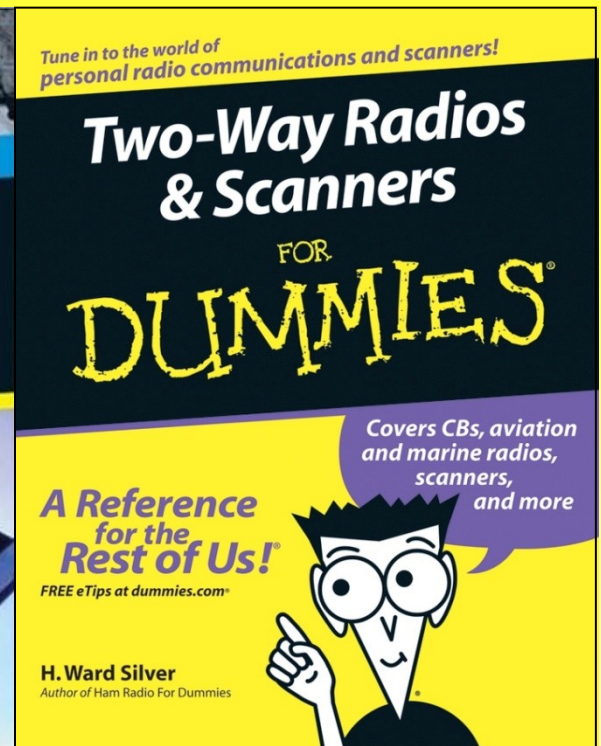
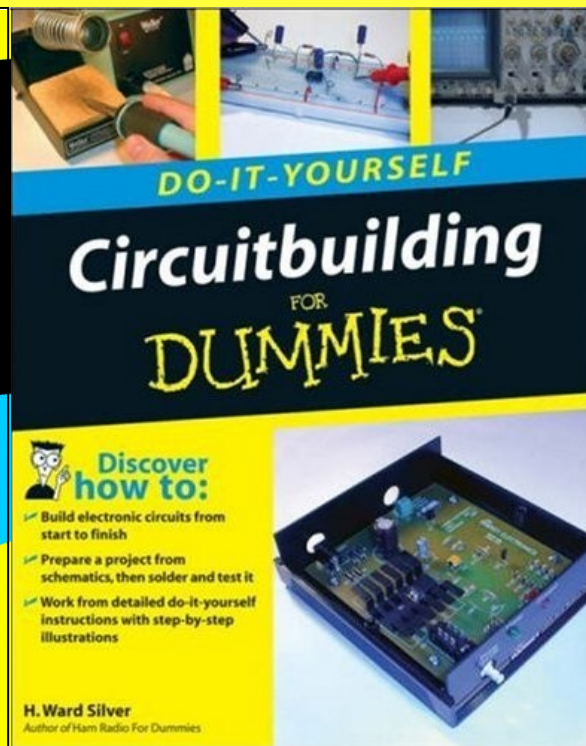
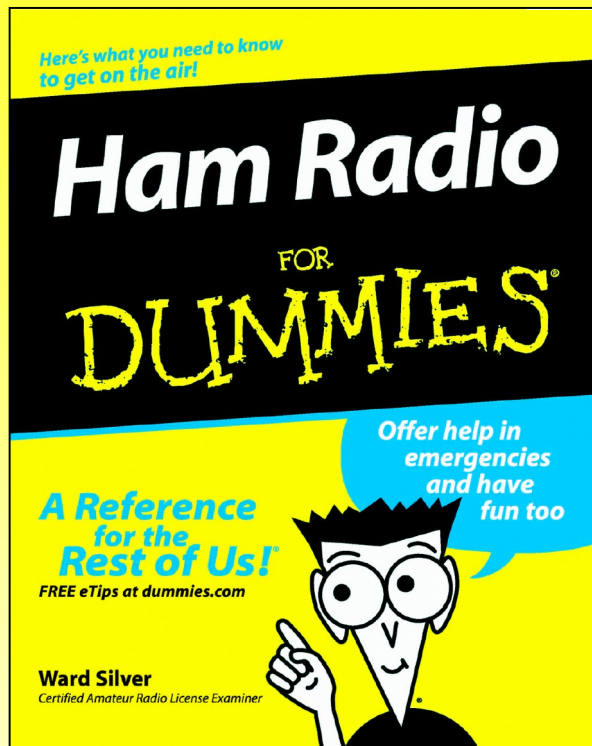
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Thank you!

Ward Silver NØAX

No Subliminal Material



Overview

Overview

- Highlights of ARRL course EC-009
- Basic Antennas: Ground Plane / Dipole
- How Gain and Nulls are Formed
- How Phased Arrays and Beams Work
- Loop Antennas

Antenna Design & Construction

ARRL EC-009

- **25 hours (plus projects) over 8 weeks**
 - adds transmission line and practical considerations
- ***Simple and Fun Antennas for Hams***
- **Mentor assigned to help each student**
- **Costs \$65 for ARRL members**
- **Good prep for Antenna Modeling, EC-004**

The Basics - 1

- Antennas radiate (or receive) because electrons are moving (or are caused to move) **back and forth** in their *elements*
- Electrons move because of and **parallel to** electric, or “*E-fields*”
- Radio or *electromagnetic* waves are both an E- and H- (magnetic) field

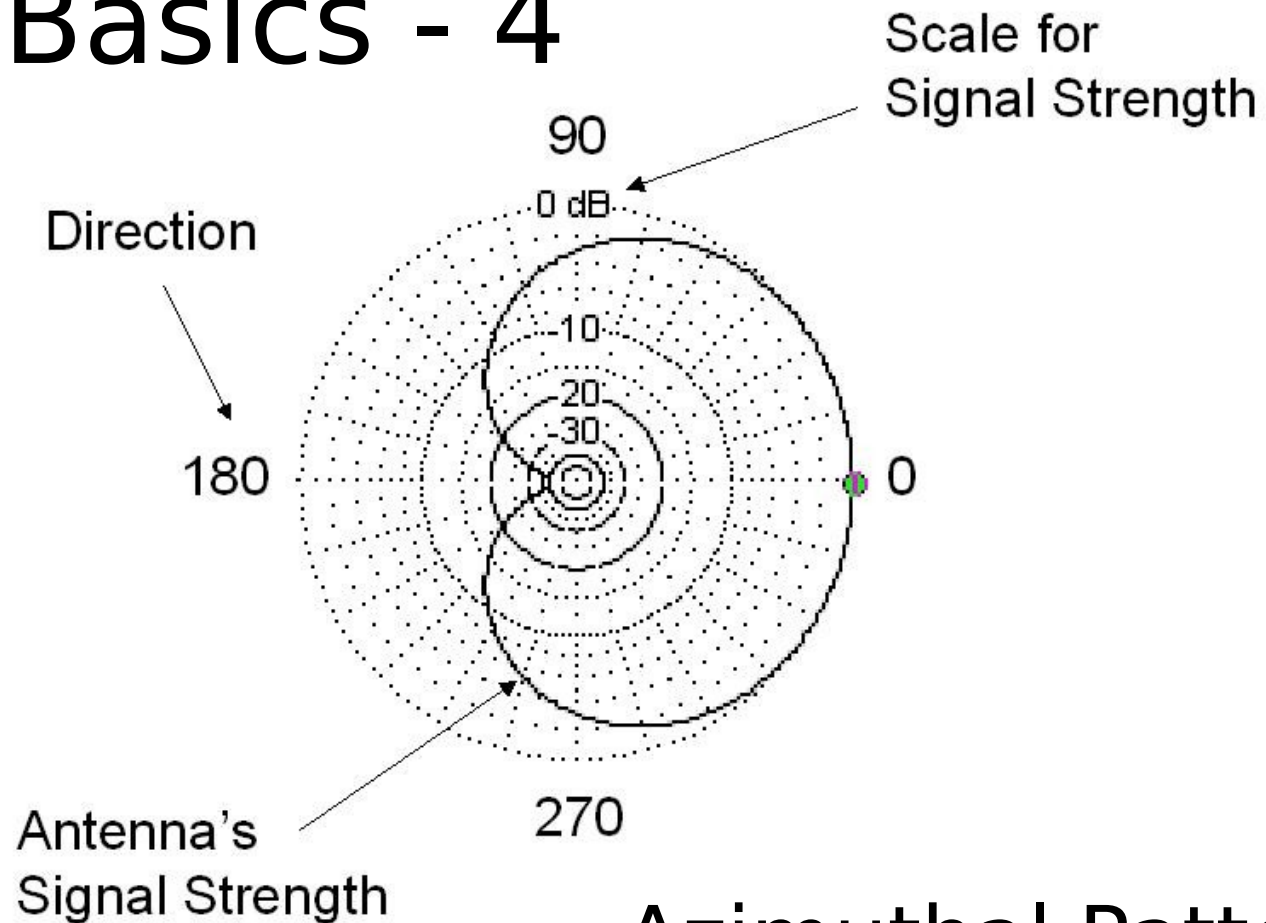
The Basics - 2

- The orientation of the E-field determines the *polarization* of the wave because that's what **makes the electrons move (current)**
- Antennas transmit & receive radio waves in the same way
- The *radiation pattern* shows how antennas distribute energy in space

The Basics - 3

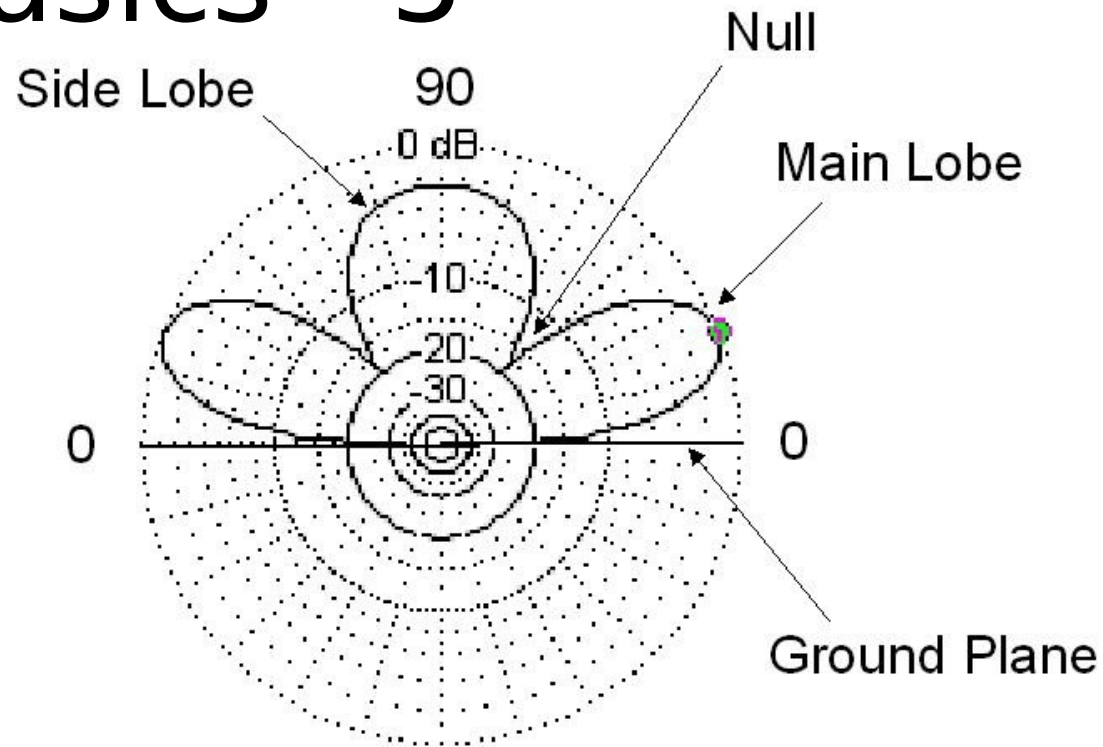
- decibels (dB) = $10 \log (\text{power ratio})$
- Impedance = ratio of Voltage to Current
- Feedpoint - place where power is applied

The Basics - 4



Azimuthal Pattern

The Basics - 5



Elevation Pattern

The Basics - 6

- Front-to-Back, Front-to-Side, and Front-to-Rear ratios
- Beamwidth - angular width of main lobe
 - Angle between the two points at which power is $\frac{1}{2}$ that at the peak (-3 dB points)

The Basics - 7

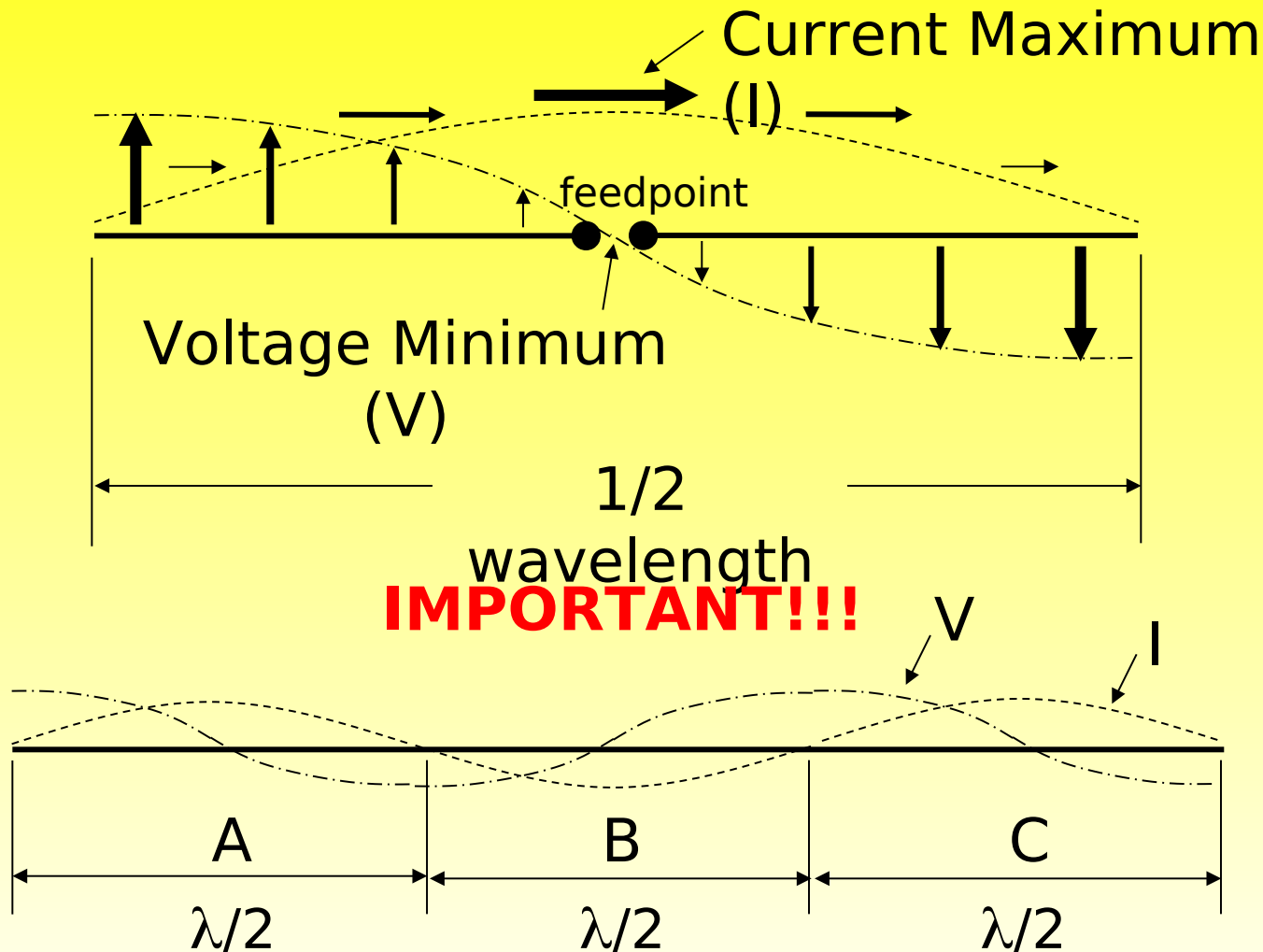
- Gain is a relative measure of effectiveness
- Gain is always ***with respect to a reference***
 - dBi (isotropic), dBd (free-space dipole)
 - Dipole has 2.2 dBi gain
 - Ground plane has equivalent gain to dipole
 - 3-element Yagi may have up to 5 dBd

QUESTIONS??

The Dipole - 1

- Oldest and simplest form of antenna
- Similar to a vibrating string's fundamental
- Wherever it's excited...
 - Current maximum in the middle
 - Voltage maximum at the ends
- Pattern repeats every $1/2$ -wavelength
 - Direction or amplitude is reversed

The Dipole - 2



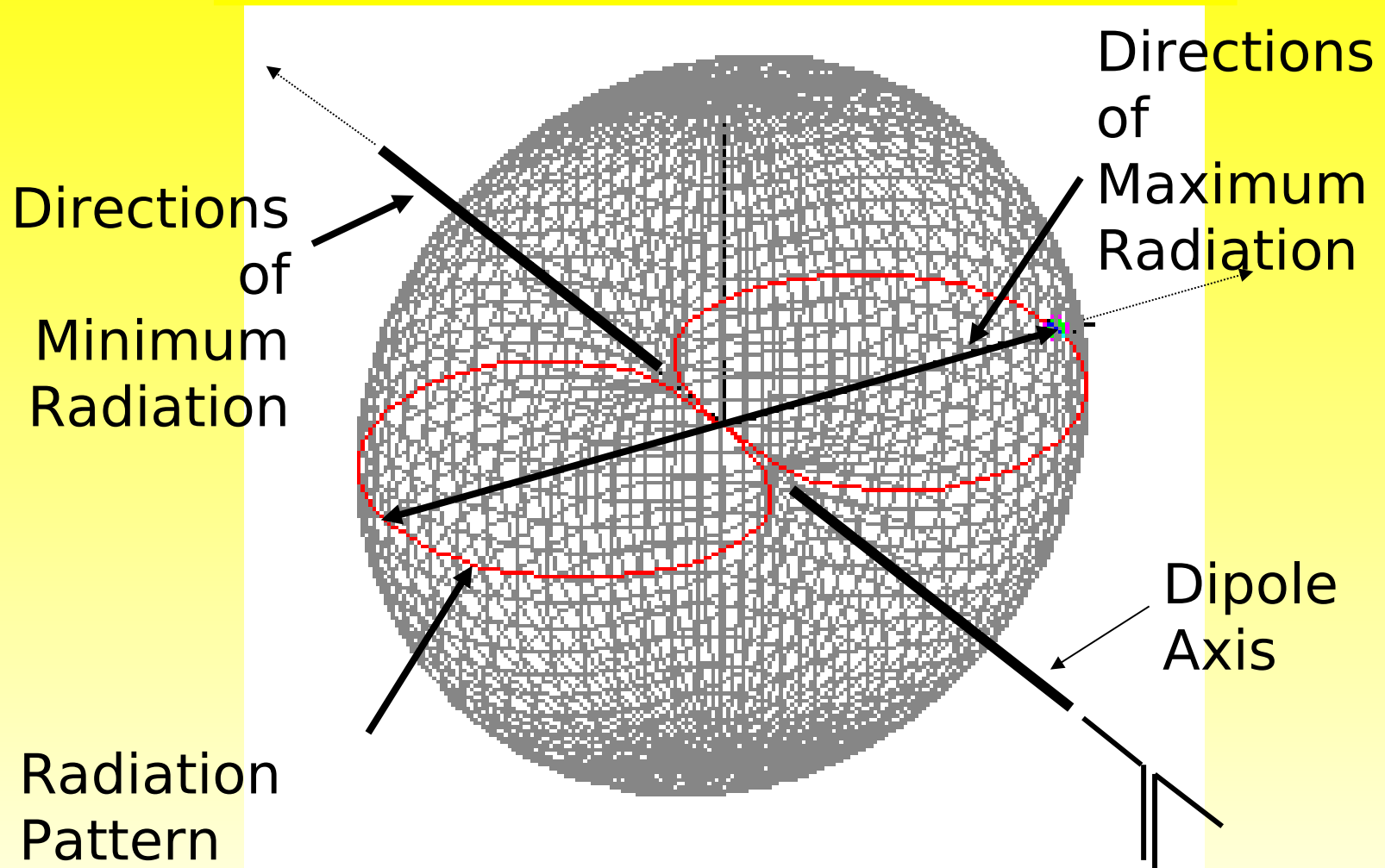
The Dipole - 3

- *Free-space 1/2-wavelength (λ)*
 - $\lambda = c / f$ or $300 / f$ in MHz
- *Length-to-diameter effect*
 - makes the antenna a little longer *electrically*
 - the “fatter” the conductor, the shorter it must be to act as an electrical $1/2 \lambda$
 - length in feet = $468 / f$ in MHz (accounts for the l-to-d effect)

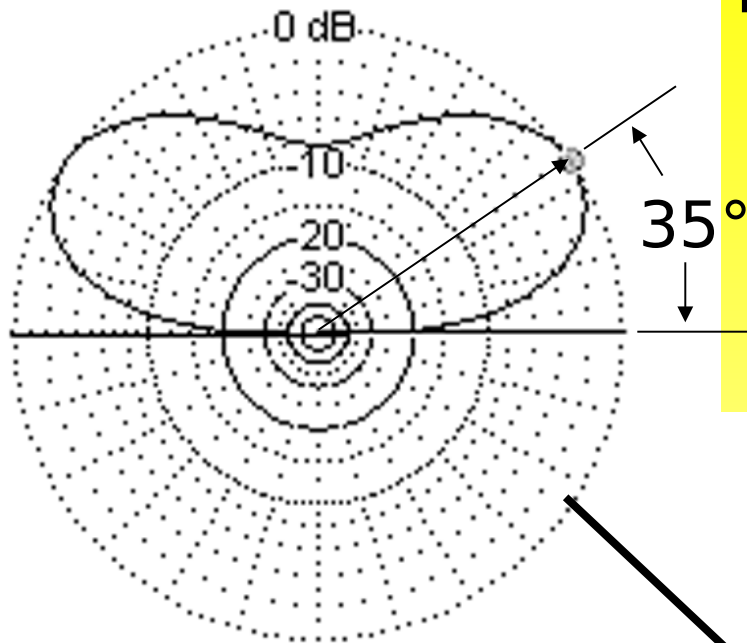
The Dipole - 4

- Radiated energy is strongest *perpendicular* to an electron's motion
 - electrons move along the length of a dipole
 - radiation strongest broadside to the dipole
- Feedpoint impedance varies with position
 - High at the ends and low in the middle
 - **Resonance** – Feedpoint impedance all resistive, no reactance

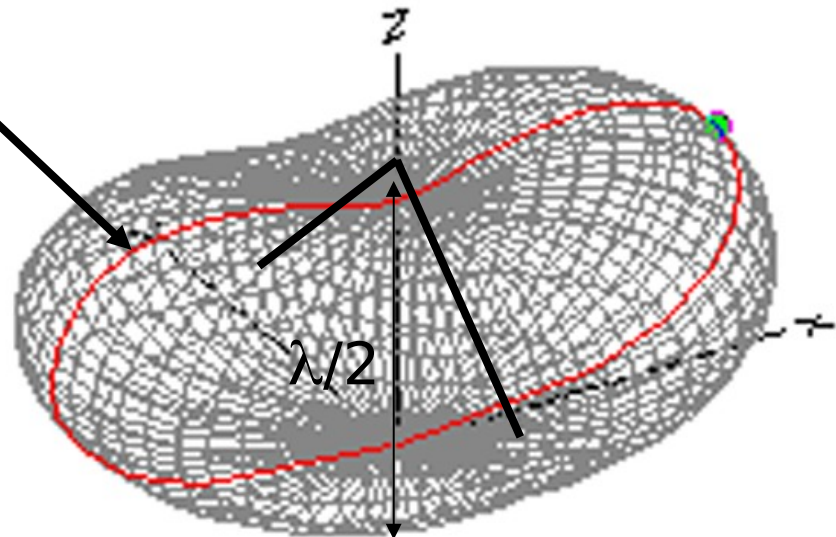
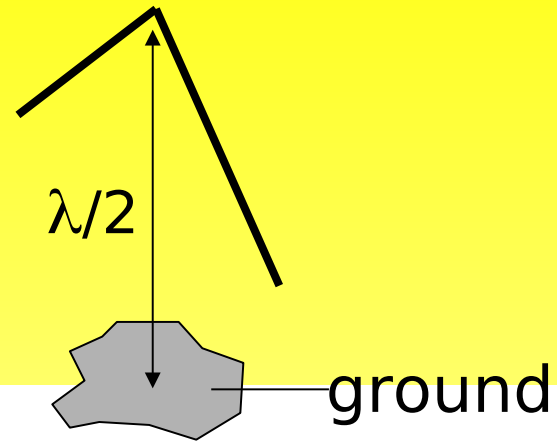
The Dipole - 5



The Dipole - 6



Inverted-Vee
Radiation
Pattern



The Dipole - 7

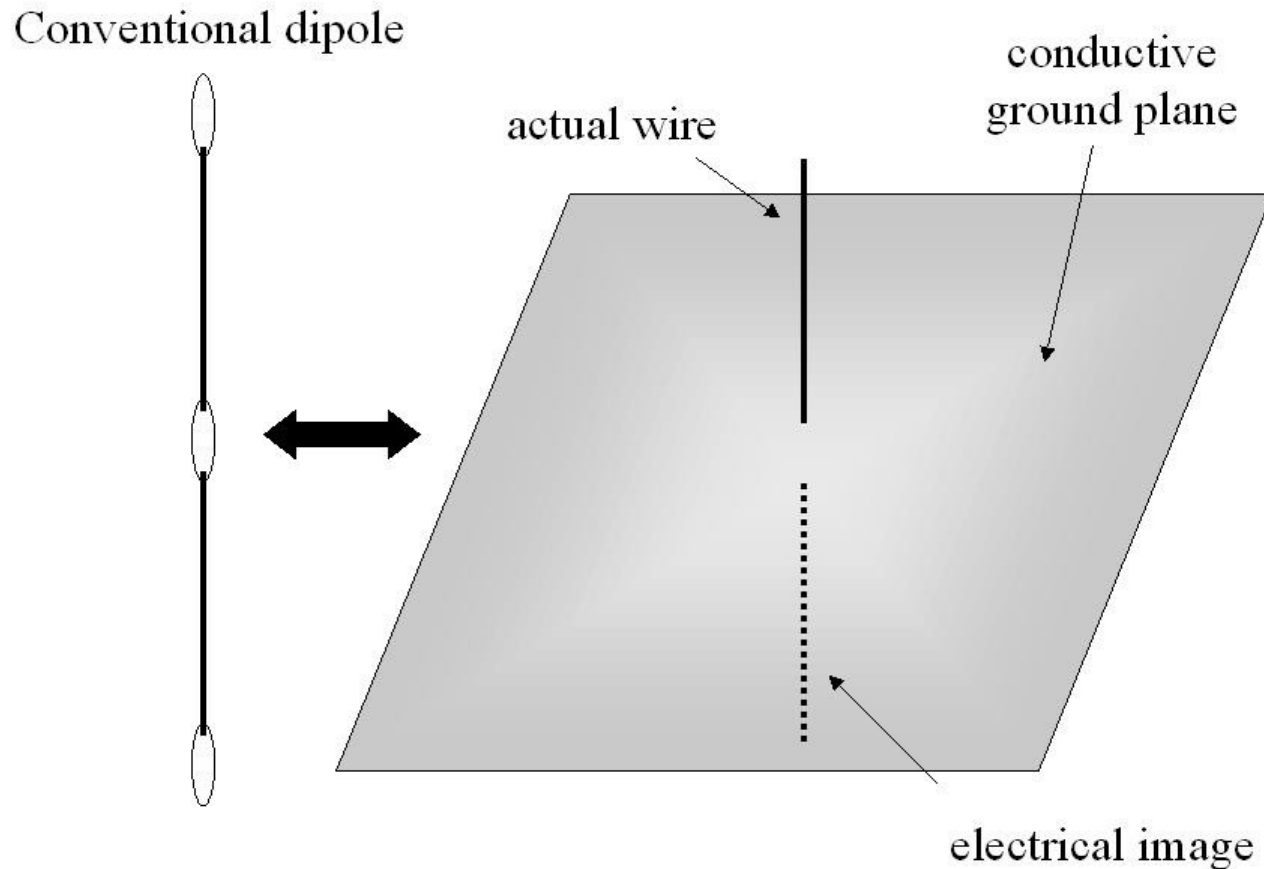
- Inverted-Vee is a “bent” dipole
- Radiation pattern adds the effect of *ground gain* from reflections
 - Can add as much as 6 dB over free space
 - Free-space gain best comparative measure
- Ground gain varies with height and with ground conductivity

QUESTIONS??

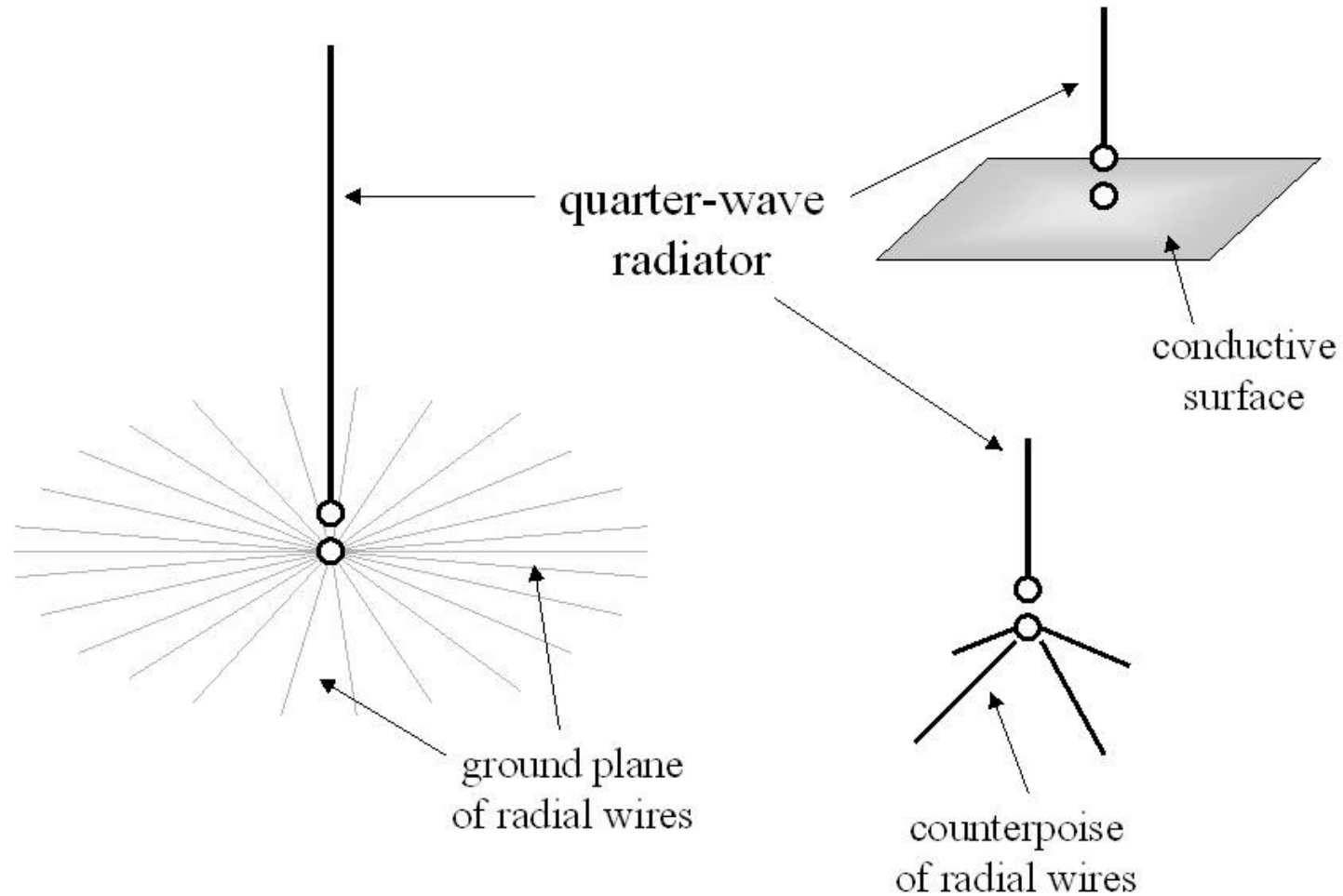
The Ground Plane - 1

- Start with a vertical dipole in free-space
- Cut off one half of the dipole
- Replace the missing half with a *ground plane* or *counterpoise*
- *Omnidirectional* if oriented vertically
- Also called a *monopole*

The Ground Plane - 2

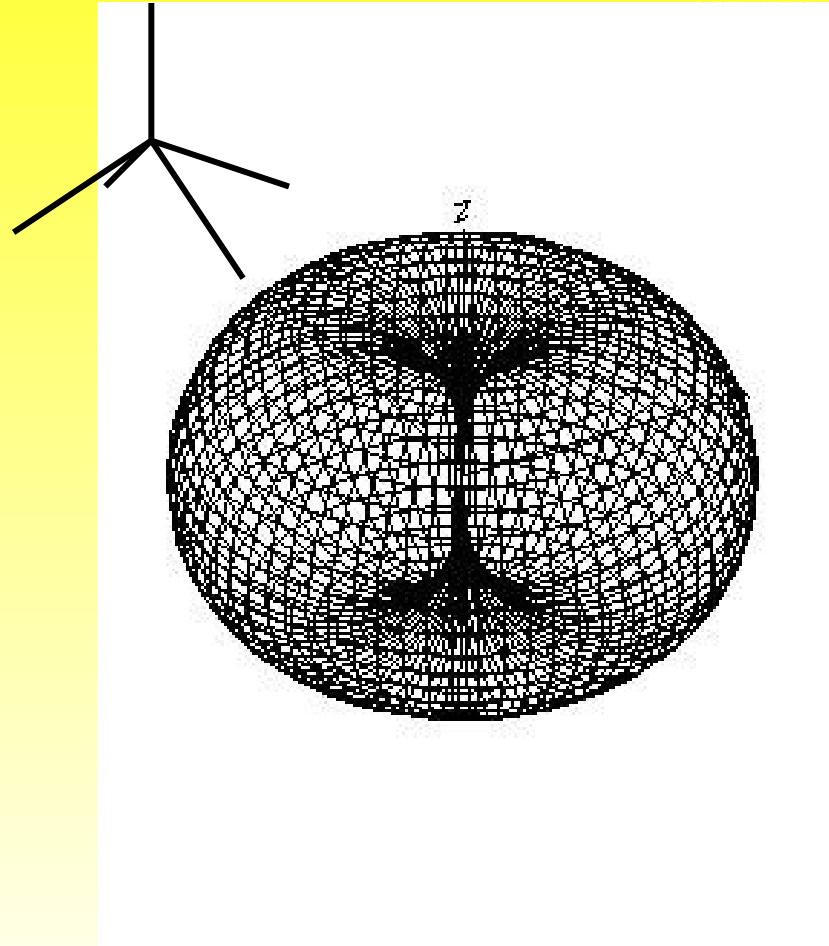


The Ground Plane - 3



The Ground Plane - 4

- Equal radiation broadside
- Nulls along the axis



The Ground Plane - 5

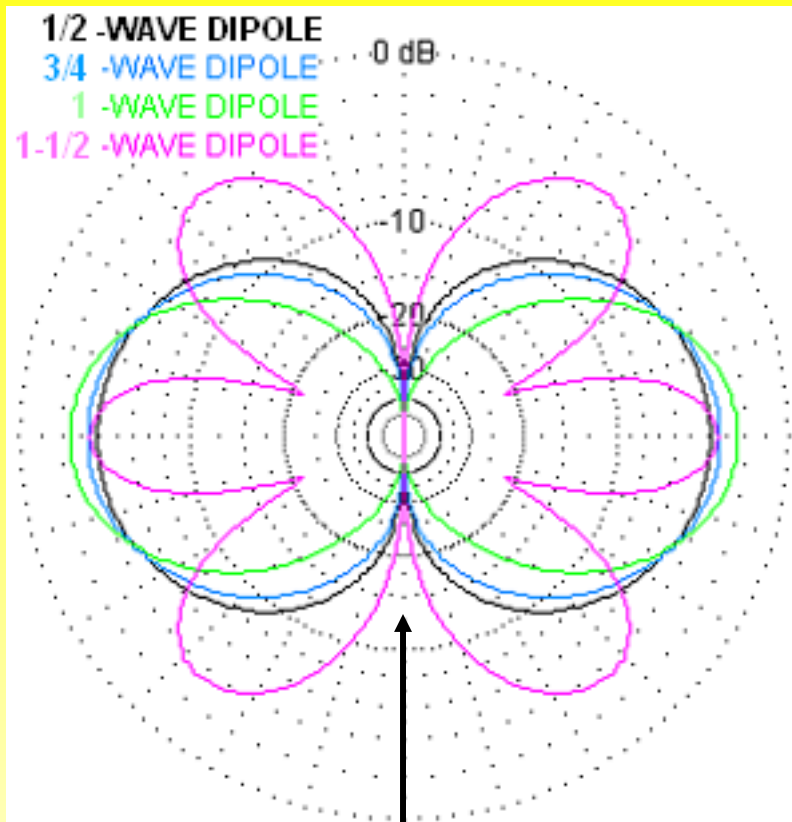
- Length (ft) = $234 / f$ (MHz)
 - $231 / f$ if #14 wire used, - 221 if 5/8" tubing
- Feedpoint impedance approx. 35Ω
 - if radials used, sloping increases feedpoint impedance
 - approximately 45° of droop gives best match
 - halfway between dipole (72Ω) and ground plane (35Ω)

QUESTIONS??

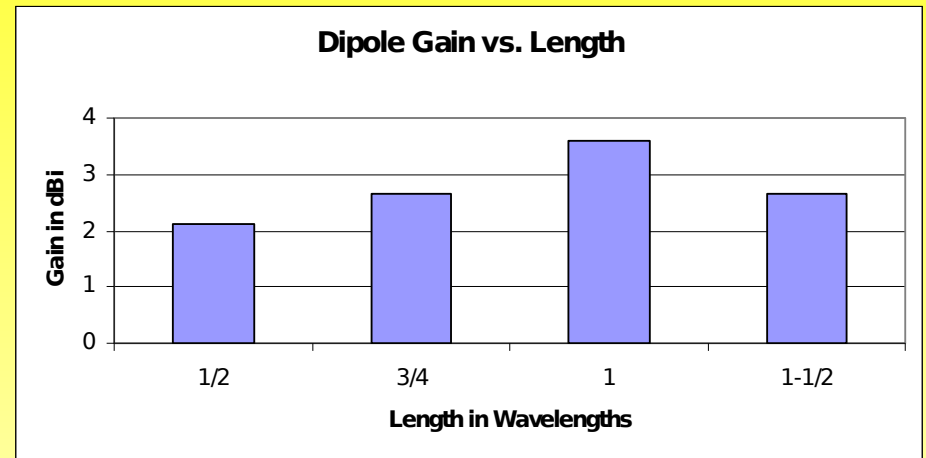
Antennas with Gain - 1

- Gain is obtained by “directing” more energy in some directions
- Gain is created by arranging currents so that their radiated fields add together
- Current can be added in separate elements, by folding or bending, or by simply lengthening a single element

Antennas with Gain - 2



Dipole
axis

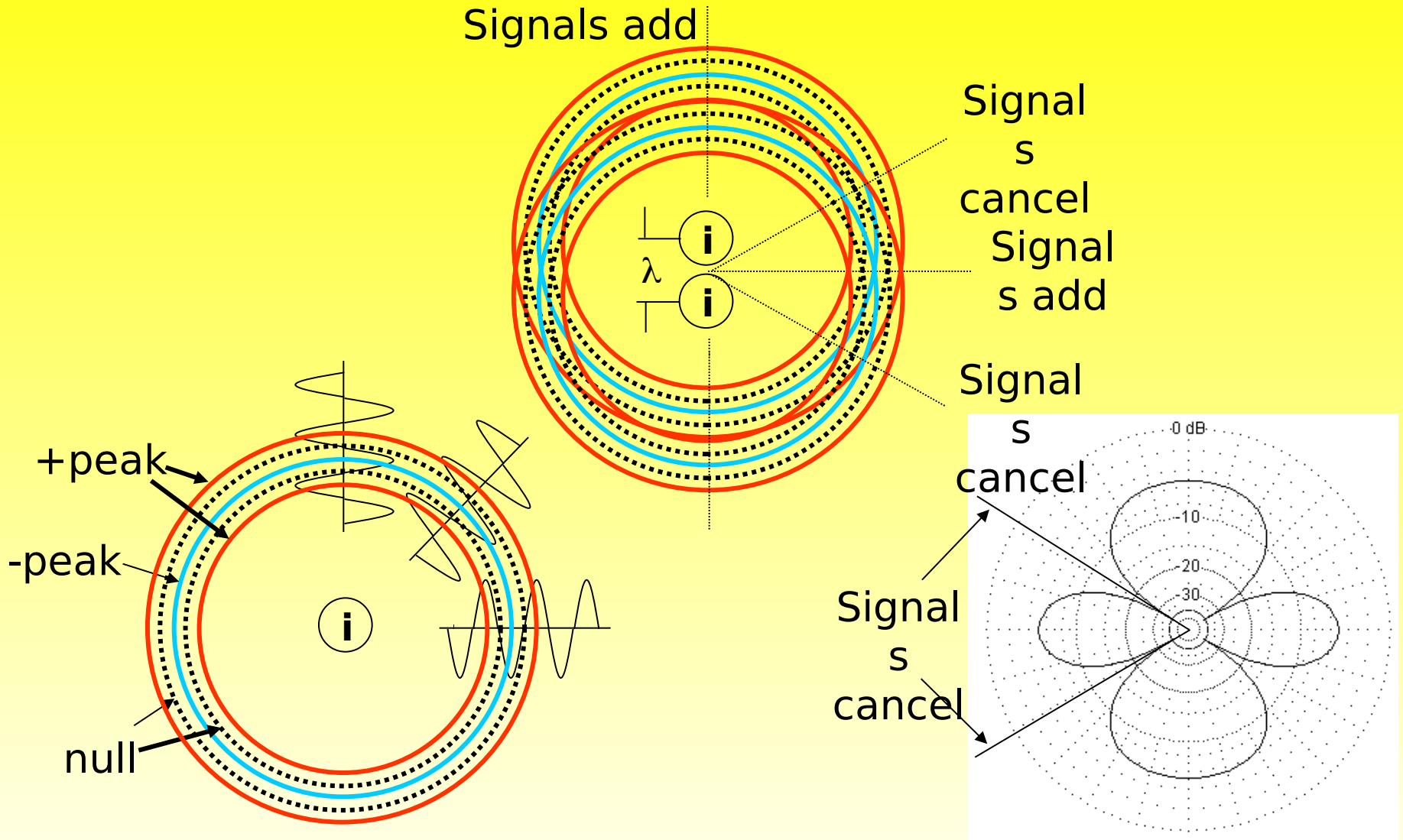


Lengthening the Dipole

Antennas with Gain - 3

- Fields from currents along the antenna can reinforce each other
 - reinforcement at large distances ($\gg \lambda$)
 - this is the *far field*
- Reinforcement may occur at angles far from broadside
- Reinforcement: *constructive interference*

Antennas with Gain - 4



Antennas with Gain - 5

- Reinforcement for gain also causes destructive interference, creating *nulls*
- Nulls are good, too!
 - Avoid interference (both to and from)
 - Improve signal-to-noise ratio in desired directions
- Adding elements also creates gain
 - E-fields can add or cancel

QUESTIONS??

Phased Arrays - 1

- *Array* - multiple antenna elements
- *Phased* - pattern created by phase differences in each element (all driven)
- *Broadside* - maximum radiation perpendicular to the plane of the array
- *End-Fire* - maximum radiation in the plane of the array

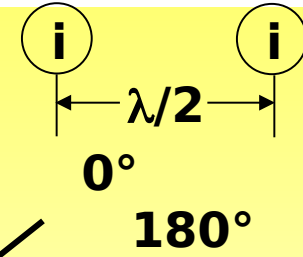
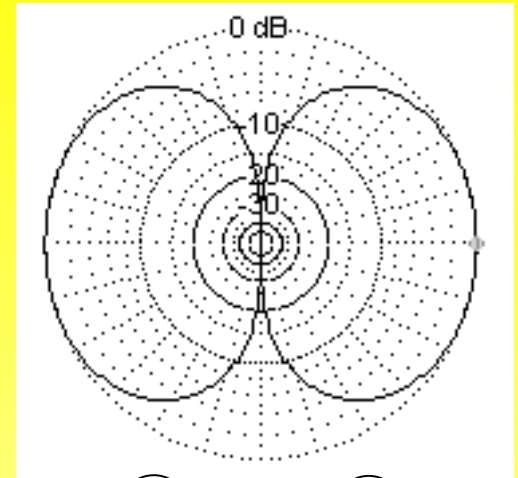
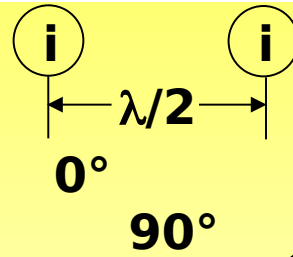
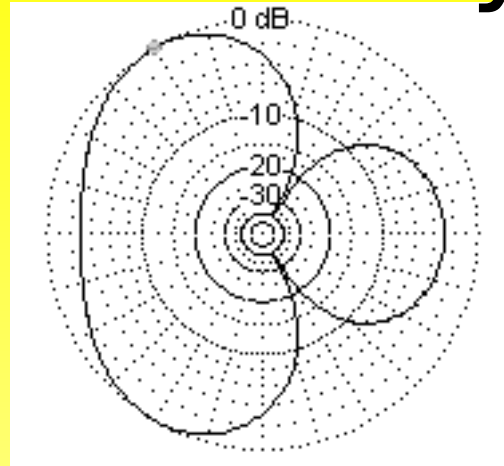
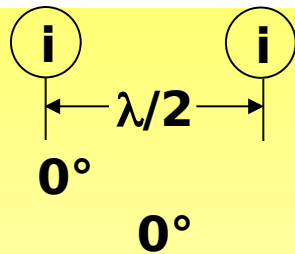
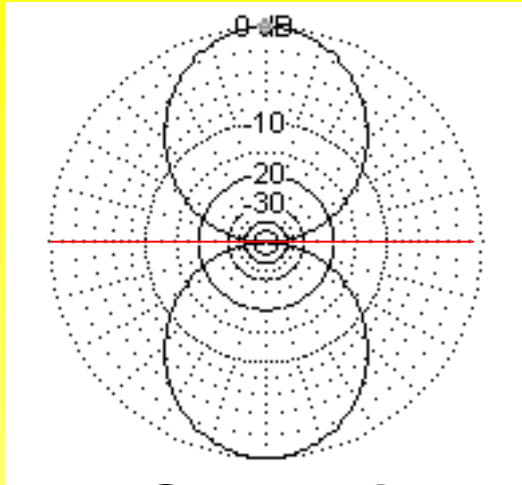
Phased Arrays - 2

- The original beam antennas
- Most constructed from $\lambda/2$ dipoles or $\lambda/4$ ground-planes
- Array plane can be vertical or horizontal
- Symmetrical arrays (including feeds) have symmetric patterns

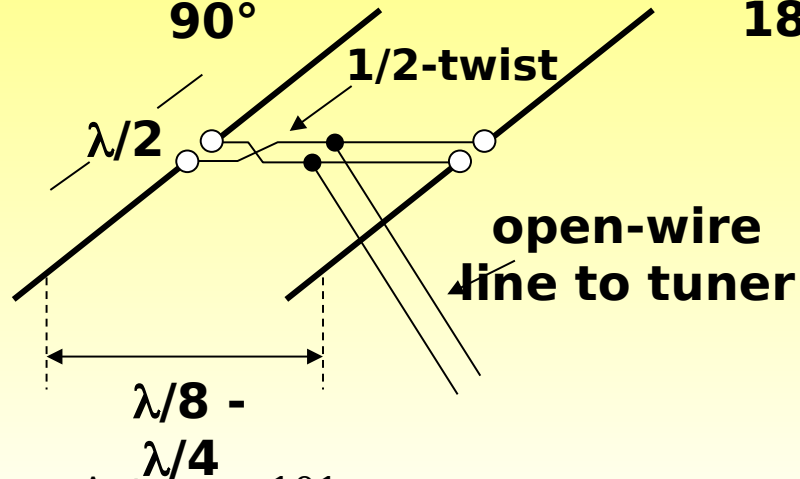
Phased Arrays - 3

- Common End-Fire Arrays
 - W8JK (two dipoles, out-of-phase, hor. plane)
 - Two-vertical array (switchable array)
- Common Broadside Arrays
 - Half-square (two vertical elements)
 - Bi-square (like a Lazy-H, but one support)

Phased Arrays - 4

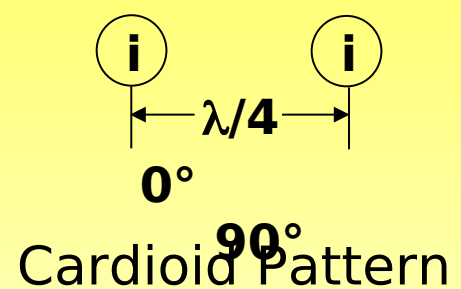
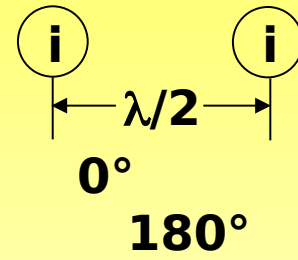
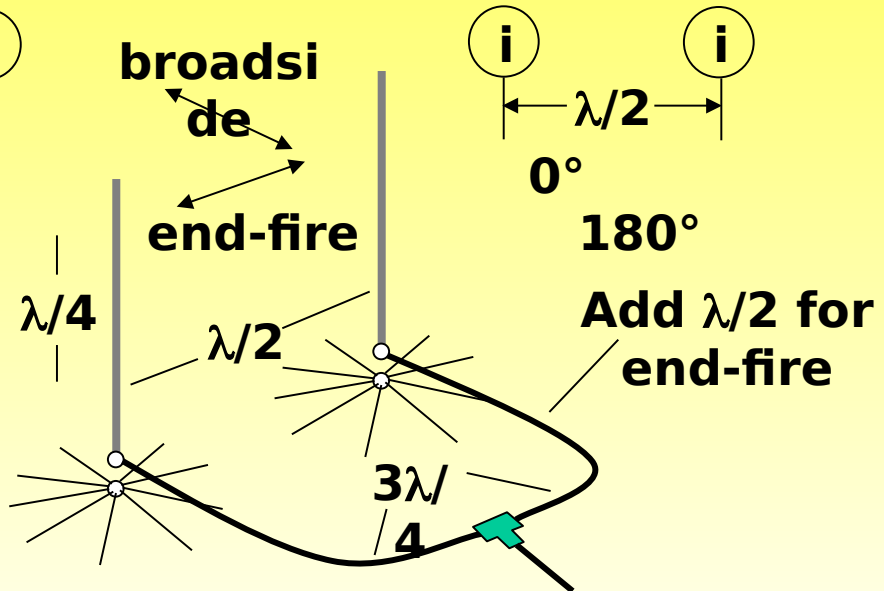
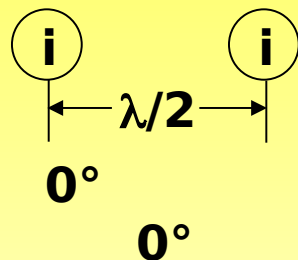
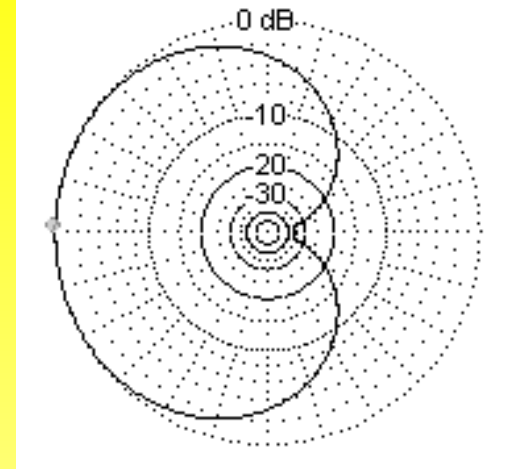
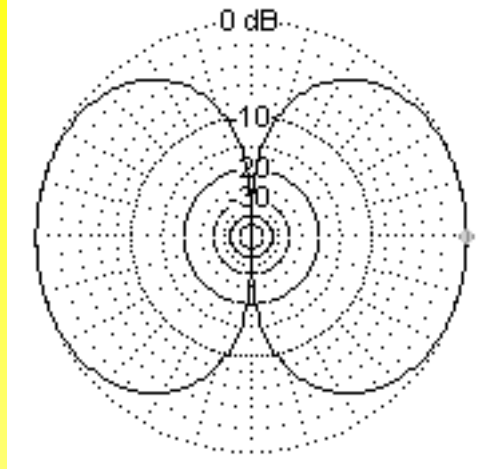
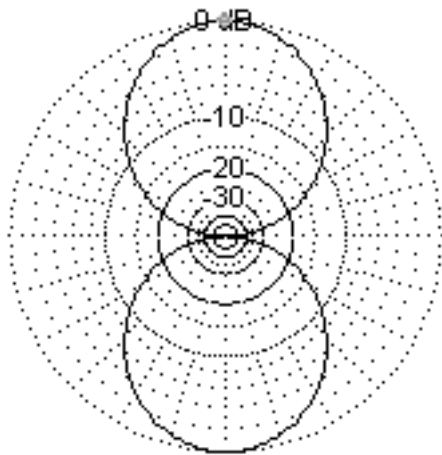


W8JK Array



Antennas 101

Phased Arrays - 5

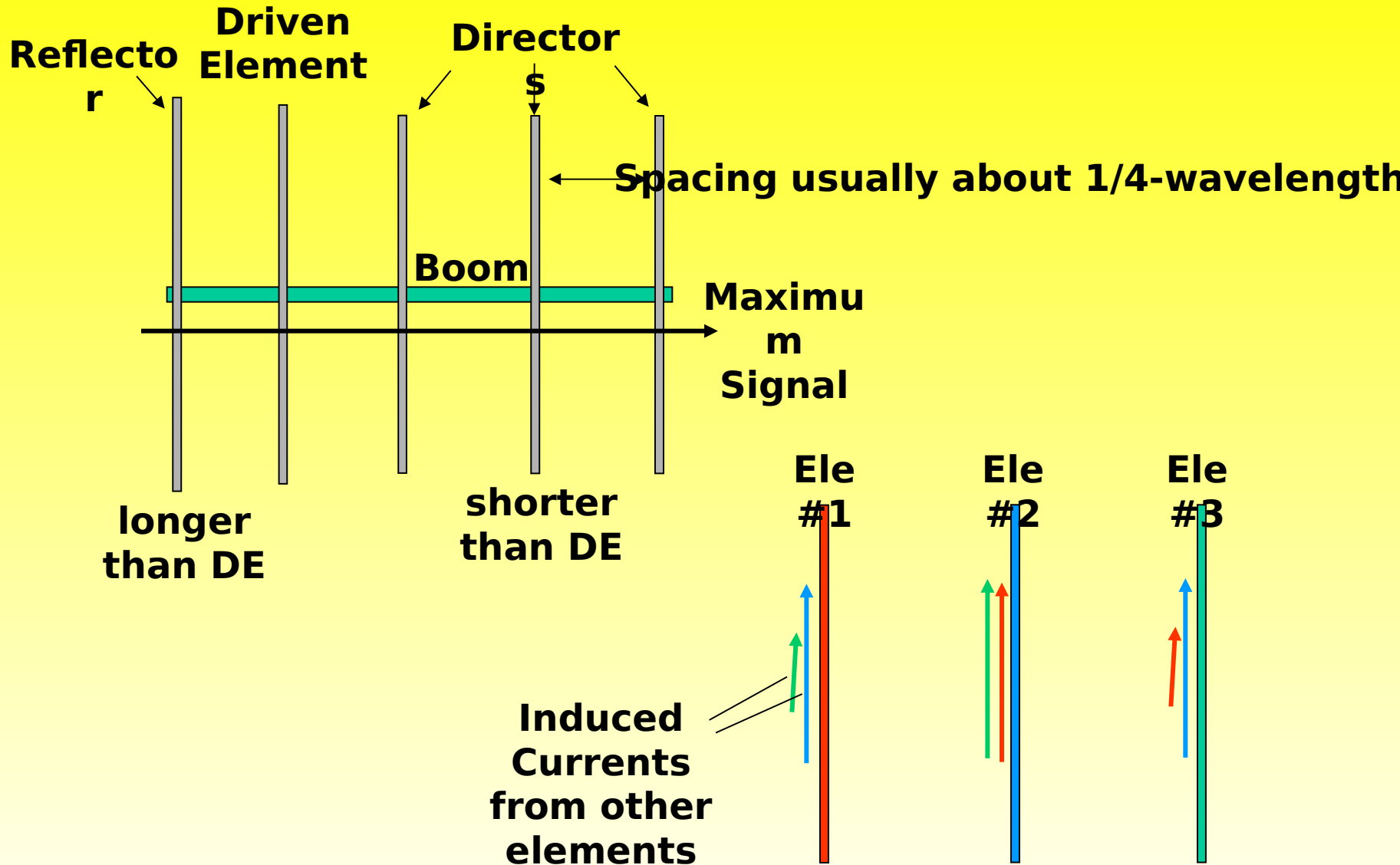


QUESTIONS??

Beam Antennas - 1

- Most accurately called *parasitic arrays*
 - non-driven elements that re-radiate energy to form the pattern are *parasitic elements*
- Usually refers to *Yagi-Uda arrays*
- Length and spacing of the elements determines the phase of the re-radiated signals

Beam Antennas - 2

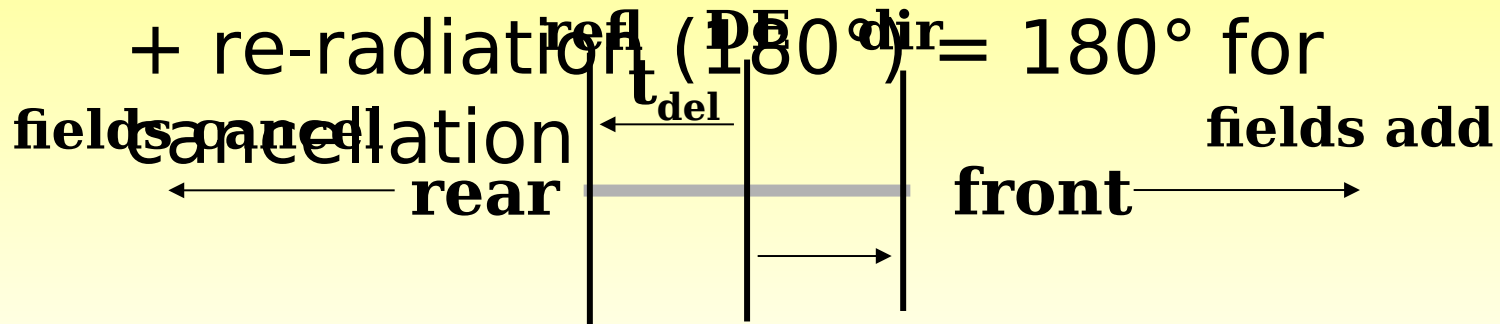


Beam Antennas - 3

- Driven element (resonant)
 - Current & voltage in-phase
- Reflector (longer than resonant)
 - Inductive, current lags 90°
- Director (shorter than resonant)
 - Capacitive, current leads 90°
- Reradiation
 - 180° out of phase with inducing field

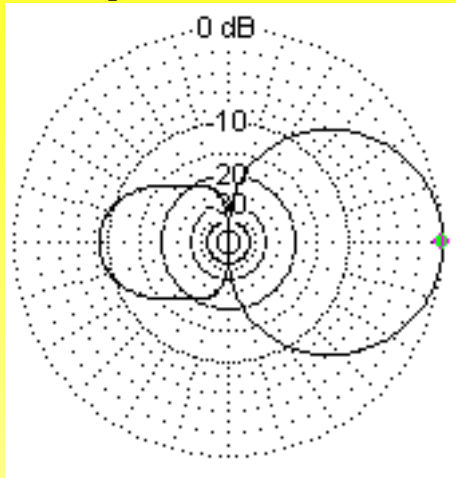
Beam Antennas - 4

- To the front:
 - 0° at DE + travel delay (t_{del}) + director lead + re-radiation (180°) = 360° for reinforcement
- To the rear:
 - 0° at DE + travel delay - reflector lag + re-radiation (180°) = 180° for cancellation

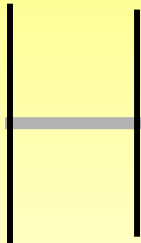


Beam Antennas - 5

Reflector & Driven (preferred)



Refl DE 2-element
Yagi



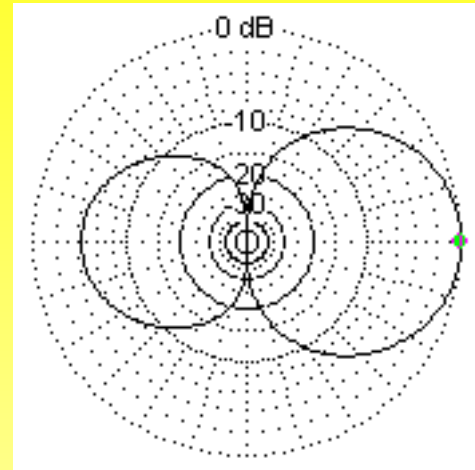
4.3 dBd

8.6 dB

F/B

BW 69°

Driven Element & Director



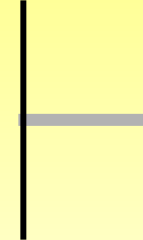
2-element DE Dir
Yagi

3.1 dBd

4.4 dB

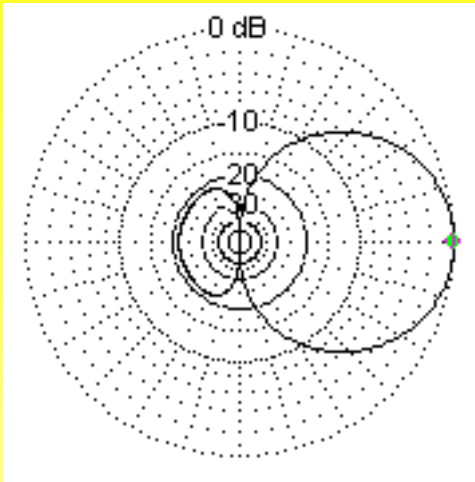
F/B

BW 71°



**dBd = gain over a
dipole**

Beam Antennas - 6

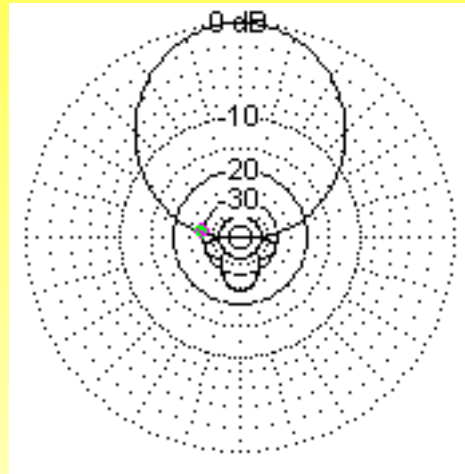


**3-element
Yagi**

4.9 dBd

21 dB F/B

BW 61°

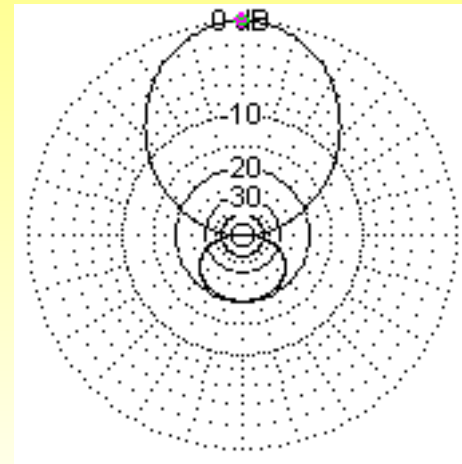


**4-element
Yagi**

5.9 dBd

24 dB F/B

BW 63°



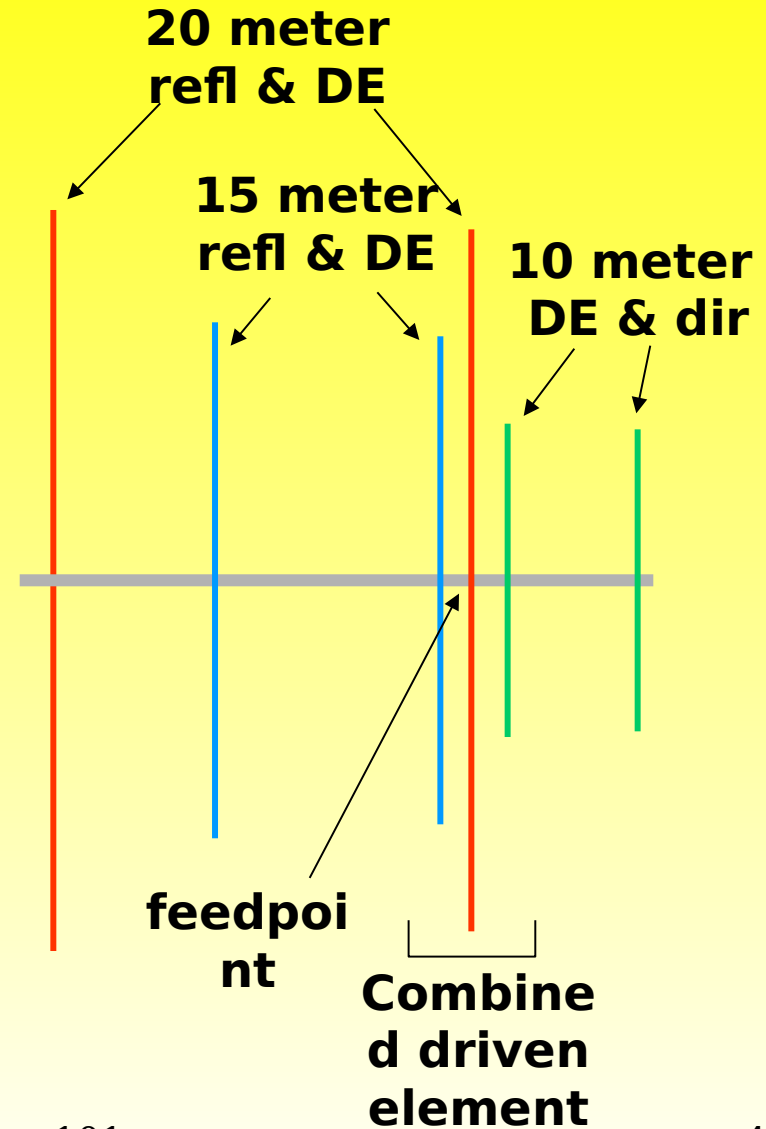
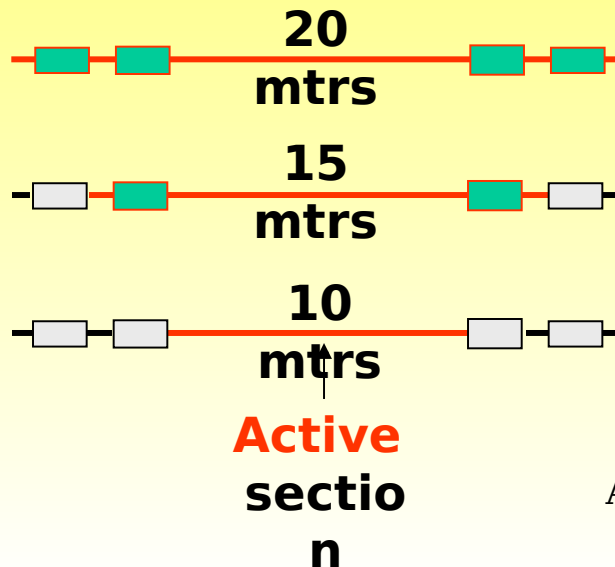
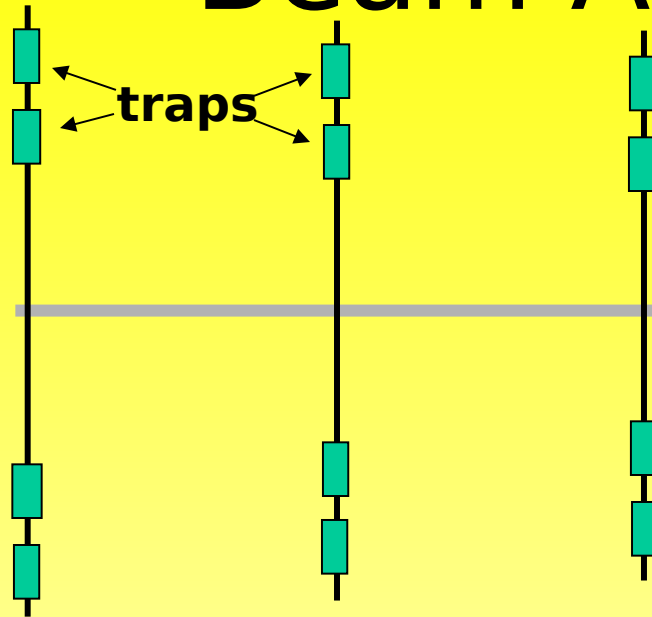
**5-element
Yagi**

7.2 dBd

20 dB F/B

BW 57°

Beam Antennas - 7

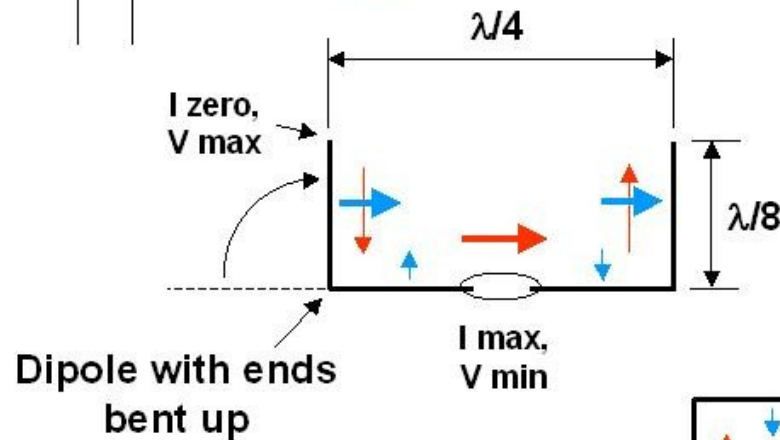
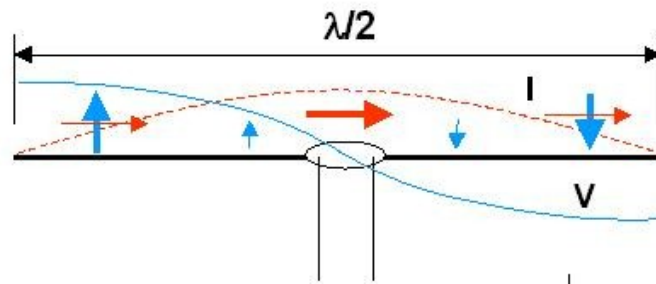


QUESTIONS??

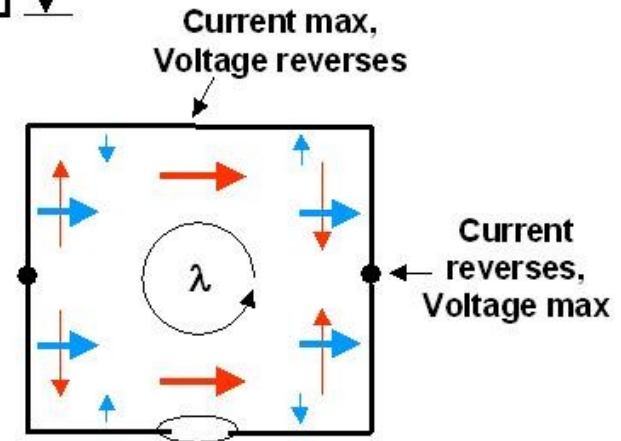
Loop Antennas - 1

- Take advantage of repeating current and voltage patterns
- Arrange antenna currents by...
 - Folding or bending the loop
 - Moving the feedpoint
- Loops have better bandwidth than parasitic and phased arrays

Loop Antennas - 2



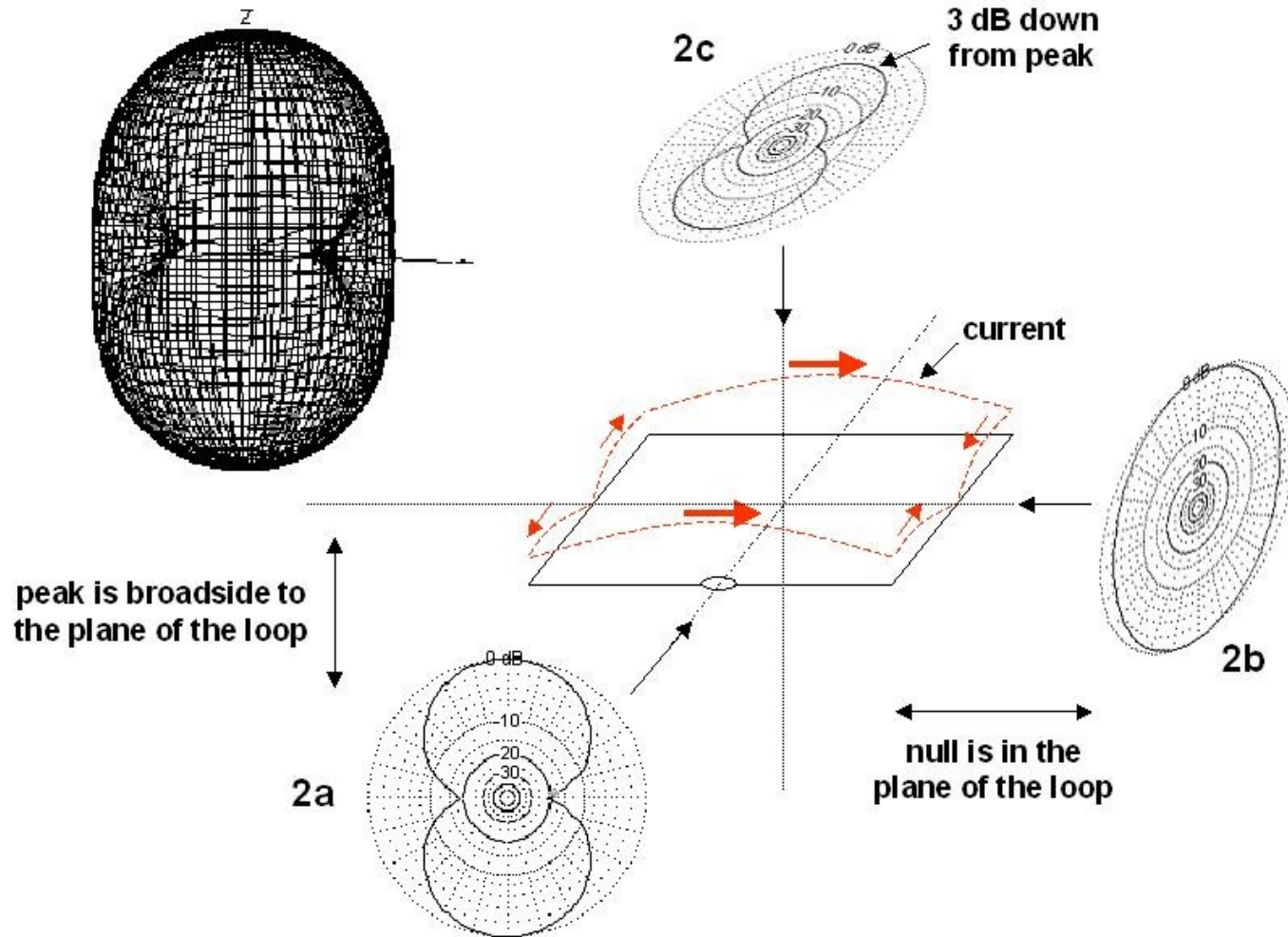
1λ Loop
two dipoles with
ends connected
together



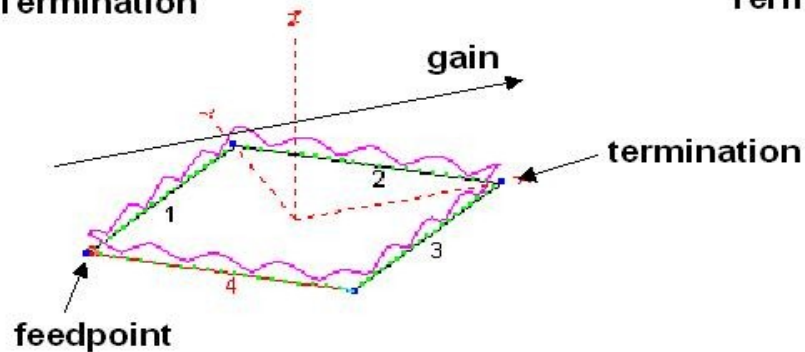
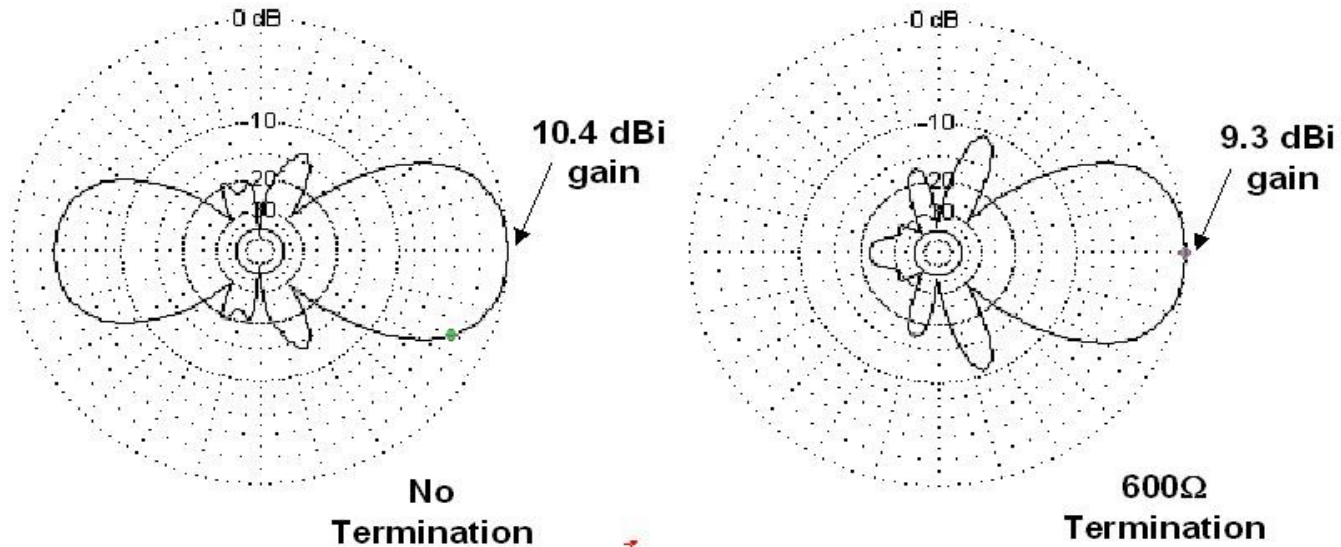
Loop Antennas - 3

- 1λ loops can be used as array elements
 - Quads and Quagis
- Polarization and pattern are controlled by feedpoint placement
- Multiple- λ loops develop gain in the plane of the loop
 - Rhombics and Vee antennas

Loop Antennas - 4



Loop Antennas - 5



Rhombics

QUESTIONS??

Useful References and Books

- ARRL Publications
 - *Antenna Book*
 - *Compendium* and *Classics* series
- RSGB Publications
 - *Practical Wire Antennas* and *HF Antennas for all Locations*
- WorldRadio
 - *Aerials I, II, & III* by Kurt N. Sterba

Useful On-Line References

- ARRL Technical Information Service
- AC6V.com (and other portal type sites)
- L.B. Cebik's Web site - www.cebik.com
- Antennas and TowerTalk reflectors at www.contesting.com

Thank You!